Late implant placement following ridge preservation versus early implant placement: A pilot randomized clinical trial for periodontally compromised non-molar extraction sites

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Abstract: AIM To compare late implant placement following alveolar ridge preservation (LP/ARP) and early implantation (EP) in periodontally compromised non-molar extraction sites with respect to soft tissue levels, esthetics, and patient-reported outcomes. MATERIALS AND METHODS Sixteen patients were randomly allocated to groups LP/ARP (n = 9) or EP (n = 7). Group LP/ARP received ARP using deproteinized bovine bone mineral containing 10% collagen and a native bilayer collagen membrane, and group EP received only extraction. Implant placement was performed 4-8 weeks post-extraction in group EP and 4 months post-alveolar ridge preservation in group LP/ARP. The soft tissue levels, pink/white esthetic scores, and periodontal parameters were evaluated 1-year post-loading. Patient's discomfort level was evaluated at the time of extraction/ARP and implant placement. RESULTS No implant failure or biologic complications occurred. There was no statistically significant difference in the median change of the midfacial mucosal margin (0.03 for group LP/ARP, -0.19 mm for group EP) and the mesial/distal papilla (0.62/0.25 mm for group LP/ARP, 0.29/-0.5 mm for group EP), pink/white esthetic scores, periodontal parameters, and patient's discomfort between the two groups. CONCLUSION Both implant placement protocols led to comparable outcomes in soft tissue levels, periodontal parameters, and patient's discomfort level.

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Late implant placement following ridge preservation versus early implant placement: A pilot randomized clinical trial for periodontally compromised non-molar extraction sites

Running title: Different implant placement protocols

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Conflict of interest

No potential conflict of interest relevant to this article was reported.

Abstract

Aim: To compare late implant placement following alveolar ridge preservation (LP/ARP) and early implantation (EP) in periodontally compromised non-molar extraction sites with respect to soft tissue levels, esthetics, and patient-reported outcomes.

Materials and methods: Sixteen patients were randomly allocated to groups LP/ARP (n=9) or EP (n=7). Group LP/ARP received ARP using deproteinized bovine bone mineral containing 10% collagen and a native bilayer collagen membrane, and group EP received only extraction. Implant placement was performed 4-8 weeks post-extraction in group EP and 4 months post-alveolar ridge preservation in group LP/ARP. The soft tissue levels, pink/white esthetic scores, and periodontal parameters were evaluated 1-year post-loading. Patient's discomfort level was evaluated at the time of extraction/ARP and implant placement.

Results: No implant failure or biologic complications occurred. There was no statistically significant difference in the median change of the midfacial mucosal margin (0.03 for group LP/ARP, -0.19 mm for group EP) and the mesial/distal papilla (0.62/0.25 mm for group LP/ARP, 0.29/-0.5 mm for group EP), pink/white esthetic scores, periodontal parameters, and patient's discomfort between the two groups.

Conclusion: Both implant placement protocols led to comparable outcomes in soft tissue levels, periodontal parameters, and patient's discomfort level.

Keywords: Alveolar ridge preservation, Dental implant, Esthetics, Soft tissue, Patient-reported outcome

Clinical relevance

Scientific rationale for study:

There is limited scientific evidence that compares different implant placement protocols and reports post-loading outcomes following alveolar ridge preservation. Moreover, there is a lack of information about implant-related outcome for periodontally compromised teeth

Principal findings:

The change of soft tissue levels (midfacial mucosal margin and papillae), pink/white esthetic scores, periodontal indices, and patient-reported outcomes were comparable between late implant placement following alveolar ridge preservation and early implant placement in periodontally compromised non-molar extraction sites.

Practical implications:

Late implant placement following alveolar ridge preservation and early implant placement present similar clinical outcomes in periodontally compromised non-molar extraction sites.

Introduction

Dental implants are a predictable treatment option for replacing missing teeth. In both partial and full edentulism, functional advantage as well as high survival have been reported with implants (Quirynen, M. et al., 2014). Depending on the needs and indications, there are different protocols to place an implant, such as immediate implant placement (at the time of tooth extraction), early implant placement (4-8 weeks post-extraction), and late implant placement (>4-6 months post-extraction) (ST, C. and D, B., 2008). Several pre-clinical and clinical researches have elaborated optimization of these protocols, suggesting the importance of understanding the biology of post-extraction sites (Buser, D. et al., 2017, Chappuis, V. et al., 2017, Thoma, D. S. et al., 2014, Vignoletti, F. and Sanz, M., 2014).

The alveolar bone undergoes resorption and remodeling after tooth extraction, resulting in 29-63% horizontal and 11-22% vertical resorption (Tan, W. L. et al., 2012). Thus, the idea of alveolar ridge preservation (ARP) is to graft biomaterial into the extraction socket, generally a bone substitute material with slow substitution rate, and to provide healing time for graft consolidation with/without primary flap closure (Avila-Ortiz, G. et al., 2014). Recent data revealed reduced need for further augmentation during implant placement following ARP and high success/survival rate of the implant placed in the augmented alveolar ridge (Mardas, N. et al., 2015, Roccuzzo, M. et al., 2014).

Interestingly, there are limited clinical studies comparing the implant placement protocols (Graziani, F. et al., 2019, Tonetti, M. S. et al., 2019). Previously, the comparison was made mainly between immediate and late implant placement (De Bruyn, H. et al., 2013, Tonetti, M. S. et al., 2017), and between late implant placement with and without ARP (Cardaropoli, D. et al., 2012, Iasella, J. M. et al., 2003). Such limitation of previous research body was recently pointed out in the consensus report of the XV European Workshop in Periodontology (Tonetti, M. S. et al., 2019).

Moreover, the extraction sites in previous clinical trials generally had intact socket walls or small bone deficiencies. However, many teeth to be extracted in routine clinical practice generally exhibit moderate to severe alveolar bone loss, indicating the necessity of expansion of these protocols to include deficient sites (Lee, J. S. et al., 2018).

The aim of the present randomized clinical trial was to compare late implant placement following ARP (group LP/ARP) and early implant placement (group EP) in periodontally compromised non-molar extraction sites with respect to soft tissue levels, esthetics, and patient-reported outcome measures.

Materials and methods

Study design

The study was designed as a prospective, randomized clinical trial performed in accordance with the Helsinki Declaration of 1975 and its 2013 revision. Due to very limited research about comparison between implant placement protocols, the present study characterized a pilot study. The research protocol was approved by the Institutional Review Board of Kyung Hee University Dental Hospital, Seoul, South Korea (KHD IRB 1511-2) and registered at the Korean Clinical Research Information Service (KCT0004014).

Study population

Patients were enrolled between March 2016 and January 2017 in the Department of Periodontology, Kyung Hee University Dental Hospital, Seoul, South Korea. Prior to participation, all participants were informed about the trial details and examined for eligibility, and written informed consents were obtained. All patients underwent appropriate periodontal treatment prior to the start of the study procedures. The inclusion criteria were age $\geqslant$20 years, adequate oral hygiene for implant therapy, and a non-molar tooth present requiring extraction and indicated for implant placement. Moreover, extraction was considered if there was $\geqslant$3 mm of hard and/or soft tissue loss in one or more socket walls (Caplanis, N. et al., 2005), but not ≥75% loss of the socket wall. Exclusion criteria were presence of smoking habit (≥10 cigarettes per day), uncontrolled systemic diseases, untreated periodontal disease, pregnancy, head and neck radiation, systematic condition and medication affecting soft and hard tissue healing, or alcoholism and drug addiction.

Study groups

The sequential numbers were randomly assigned to groups LP/ARP and EP on a basis of block randomization. The group assignment was sealed in opaque envelopes where marked matched number to random assignment number. The study participants were given enrollment numbers matched to the envelope numbers. This randomization process was performed by an independent investigator. Immediately after tooth extraction, the envelope was opened by an assistant and the assigned group was verified.

- Group LP/ARP: late implant placement (4 months post-ARP)
- Group EP: early implant placement (4-8 weeks following tooth extraction)

Bone augmentation procedure was performed if needed at the time of implant placement in both groups. Soft tissue augmentation was not allowed until the final visit.

Surgical procedures

After administering local anesthesia (lidocaine containing 1:100,000 epinephrine), flap reflection, tooth extraction, and meticulous degranulation were performed. In group EP, a cross suture was performed. In group LP/ARP, deproteinized bovine bone mineral containing 10% collagen (DBBM-C; Bio-Oss® Collagen, Geistlich Pharma AG, Wolhusen, Switzerland), was packed in the extraction socket with gentle pressure and placed up to the contour that was consistent with the adjoining ridge shape. This was followed by insertion of a native bilayer collagen membrane (NBCM; Bio-Gide®, Geistlich Pharma AG), extending at least 1-2 mm over the defect margin. An additional layer of NBCM was placed on the initial membrane, mainly around the socket entrance (Choi, H. K. et al., 2017). Subsequently, crisscross and/or interrupted sutures were performed for membrane stabilization. Maximal flap closure was performed, but primary flap closure was not attempted, leading to a partial exposure of the NBCM (Fig. 1). Sutures were removed 7-10 days later and the extraction sites were temporarily restored with fixed prostheses, designed to avoid compression of the surgical area.

In group EP, implant placement and guided bone regeneration using DBBM (Bio-Oss®, Geistlich Pharma AG) and NBCM were performed 4-8 weeks post-extraction (Fig. 1). After reflection of mucoperiosteal flaps, implants were placed according to the manufacturer's protocol (Dentium, Seoul, Korea). Sufficient primary stability was achieved in all implants. DBBM was placed at a slight over-contour compared to the adjoining ridge shape, and the grafted area was covered completely with NBCM. Primary flap closure was performed and sutures were removed after 10-14 days.

In group LP/ARP, implant placement was performed 4 months post-ARP (Fig. 1). Flap elevation was performed in all sites and implants were placed according to the manufacturer's guidelines (Dentium, Korea). Additional bone grafting procedure was performed in case of thin buccal bone

left after implant placement (<1 mm) or buccal bony dehiscence/fenestration. Depending on additional bone augmentation, a cover screw or a healing cap was connected to the implant. Primary flap closure was performed at bone-augmented sites and sutures were removed after 10-14 days.

For group EP and further bone-augmented sites in group LP/ARP, 3-5 months of healing were provided. The implant sites were then uncovered, a healing cap was connected to the implant, and the flap was sutured around the cap.

Following the surgical interventions, the patients were prescribed antibiotics and analgesics according to clinician's preference. Patients were instructed to rinse with 0.12% chlorhexidine twice a day until suture removal. At the time of suture removal (for both extraction/ARP and implant placement), visual analogue scale (VAS; 0: no pain, 10: extreme discomfort) was used to measure patient discomfort in both groups.

Follow-up

After complete soft tissue healing, the patients were referred to the Department of Prosthodontics, Kyung Hee University Dental Hospital, Seoul, South Korea for prosthetic treatment. The patients were restored with cemented or screwed fixed prosthesis according to the preference of the prosthodontists in charge. The patients were recalled on the day of the final prosthesis insertion (T0), and at 3, 6, and 12 months (T12) thereafter (Fig. 1, 2). At T0 and T12, standardized clinical photographs and dental impressions were obtained.

Outcome measures

Primary outcome

Change of the midfacial marginal mucosal level between T0 and T12

Secondary outcome

- Change of the mesial/distal papillary height between T0 and T12
- Pink/white esthetics score (PES/WES) at T12 (Belser, U. C. et al., 2009)
- Probing depth (PD), measured to the nearest 0.5 mm at T12 (UNC 15, Hu-Friedy, Chicago,

US)

- Modified plaque index (mPI) at T12 (Mombelli, A. et al., 1987)
- Modified sulcus bleeding index (mSBI) at T12 (Mombelli, A. et al., 1987)
- Patient discomfort after tooth extraction/ARP and implant placement, assessed using VAS.

Measurement of soft tissue levels

The stone cast was photographed. In a computer software (Photoshop CS6, Adobe, CA, USA), two reference lines were drawn. One was a vertical line along the long axis of the implant crown, and the other was a line connecting the highest points of the neighboring teeth. At the point where these two lines met, another line was drawn to the midfacial mucosal margin. The length of this line was measured, and the change of the length at T0 and T12 was calculated. Moreover, the length between the highest point of the incisal/occlusal line angle and papilla tip was measured mesially and distally, and the difference between T0 and T12 was calculated (Fig. 2).

Inter-examiner calibration

All measurements for soft tissue levels and PES/WES were performed by two investigators (SW. S and H-C. L). Using ten random samples irrelevant to this study, the soft tissue level was measured, resulting in an interclass correlation coefficient of 0.998 ($p < 0.05$). The two investigators measured PES/WES separately as well, and a senior investigator (S-Y. S) was involved in the evaluation in case of disagreement.

Sample size calculation

The sample size was calculated using G Power software (Faul, F. et al., 2009). The study by Palattella et al. (2008) was used for the reference value of the change of the midfacial marginal mucosal level (0.6 mm) following early implant placement (Palattella, P. et al., 2008). A change of >1.0 mm of the midfacial mucosal was considered clinically significant. Standard deviation was set to 0.6 mm (Palattella, P. et al., 2008). At least seven patients per group were required to acquire 80% power at a two-sided alpha level of 0.05%.

Statistics

The collected data were presented as mean, standard deviation, median, and quartiles. The Shapiro-Wilk test was used for conformity to normal distribution. Then, independent T-tests (change of the distal papillary height and the mid-facial margin) or Wilcoxon rank-sum tests (the rest of the parameters) were used to detect significant differences between the groups. Statistical significance was set at $p < 0.05$.

Results

This study enrolled 23 patients, but five from group EP and two from group LP/ARP dropped out because of refusal to participate in the study or change of the treatment plan and protocol violation. Consequently, seven and nine patients in groups EP and LP/ARP, respectively, completed the study (Fig. 3). The demographics of the patients are presented in Table 1.

All implants were placed successfully in both groups. However, at the time of implant placement, further bone-augmentation procedure was performed in 7/9 patients in group LP/ARP. No biologic complication was observed during the study period. One implant crown demonstrated chipping in group LP/ARP around 3-6 months after implant prosthesis insertion, but the patient did not undergo correction of the prosthesis.

Soft tissue levels

The median change of the midfacial mucosal margin between the insertion of the final prosthesis and one year was 0.03 mm (Q1: -0.35, Q3: 0.49) in group LP/ARP and -0.19 mm (Q1: -0.31, Q3: 0.46) in group EP (positive and negative numbers indicated gain and loss of tissue, respectively), and was not statistically significant ($p > 0.05$). The median changes in the mesial and distal papillae in group LP/ARP were 0.62 mm (Q1: 0.08, Q3: 0.79) and 0.25 mm (Q1: 0.08, Q3: 1.0) respectively, and that in group EP were 0.29 mm (Q1: 0.01, Q3: 0.33) and -0.5 mm (Q1: -0.51, Q3: 0.71), respectively, and the difference was not statistically significant between the groups ($p > 0.05$) (Table 2, Fig. 4).

The median value of PES at 12 months was 5 (Q1: 5, Q3: 6) in group LP/ARP and 5 (Q1: 4.5, Q3: 7) in group EP, with no statistically significant difference between them ($p > 0.05$). WES did not show a statistically significant difference between the groups ($p > 0.05$) (6, [Q1: 5, Q3: 8] for group LP/ARP; 7, [Q1: 5.5, Q3: 7] for group EP) (Table 3).

Periodontal parameters

The median PD values at 12 months were 3.25 (Q1: 2.75, Q3.5) in group LP/ARP and 2.83 mm (Q1: 2.71, Q3: 2.83) in group EP ($p > 0.05$). Difference between the values for mPI and mSBI were not statistically significant between the groups ($p > 0.05$) (Table 2).

Patient-reported outcome measures

With regard to tooth extraction with/without ARP, the median level of discomfort of the patients measured with VAS was 1 (Q1: 1, Q3: 2) in group LP/ARP and 0 (Q1: 0, Q3: 2.5) in group EP. At the time of implant placement, the median level of discomfort was 1 in group LP/ARP (Q1: 0, Q3: 2), and 3 in group EP (Q1: 1.5, Q3: 4). Intergroup differences were not statistically significant at both time-points ($p > 0.05$) (Table 2).

Discussion

The present study compared late implant placement following alveolar ridge preservation (group LP/ARP) and early implant placement (group EP) in periodontally compromised extraction sites, demonstrating no significant intergroup differences with respect to i) changes in the midfacial mucosal margin and height of the mesial/distal papilla, ii) PES/WES scores, and iii) level of patients' discomfort.

The majority of research regarding ARP targeted non-molar teeth presented minimal loss of the buccal bone plate (e.g., <50%; (Avila-Ortiz, G. et al., 2014), possibly due to standardization of the socket and relative ease of radiological and clinical assessment (less influence of septal bone between roots). However, in a general clinical setting, molar teeth are extracted more frequently (Brugger, O. E. et al., 2015). This led to the exclusive inclusion of molar teeth with minimal bone destruction in the research field (Engler-Hamm, D. et al., 2011, Jung, R. E. et al., 2018). Despite the extensive efforts, periodontally compromised extraction sockets had been rarely investigated, However, this was recently addressed in a few studies having observation periods up to implant placement (Lee, J. S. et al., 2018, Sun, D. J. et al., 2019). Longer follow-up terms with implants being loaded and examined at later time-points are still scarce. Furthermore, there has been no study comparing implant placement following ARP with other implant placement protocols.

The present study compared early implant placement with late implant placement following ARP. The timing of early implant placement, i.e. 4-8 weeks following implant placement, is considered the period after initial bone remodeling, resolution of inflammation, spontaneous tissue thickening, and gain of some newly formed bone in the apical area of the extraction socket (Buser, D. et al., 2017). This seemed to apply to periodontally compromised extraction sites in the present study. Early implant placement was feasible in all sites of group EP with guided bone regeneration. However, depending on the extent of bone destruction and the type of extraction site, some sites may require more extended healing period for placing the implant to proper position and obtaining sufficient primary stability.

Nowadays, soft tissue stability is considered very important in esthetics and peri-implant health (Thoma, D. S. et al., 2018). At 1-year post-loading, median changes of the midfacial mucosal margin were 0.03 mm in group LP/ARP (gain) and -0.19 mm in group EP (recession) with no

statistically significant difference between the groups. With respect to the two treatment modalities used in this study, previous reports on the changes in the midfacial mucosal level were: -0.39 ± 0.54 mm at 10 years (Roccuzzo, M. et al., 2014) and -0.1 ± 0.3 to 0.9 ± 1.0 mm at one year (Cosyn, J. et al., 2015) for ARP sites, and -0.18 ± 0.58 mm at one year (Buser, D. et al., 2009) and -0.17 mm between one year and 10 years (Chappuis, V. et al., 2018) for early implantation sites. Differences in the studies could be due to variability in the inclusion criteria of the extraction site [none specified (Roccuzzo, M. et al., 2014) or potentially different severity of bone and/or soft tissue deficiencies (Buser, D. et al., 2009, Chappuis, V. et al., 2018, Cosyn, J. et al., 2015)], different follow-up periods (Chappuis, V. et al., 2018, Roccuzzo, M. et al., 2014), and addition of soft tissue augmentation procedure (Cosyn, J. et al., 2015). To summarize, the obtained data indicated that early implant placement and late implant placement with ARP were predictable treatment modalities with respect to the level of the midfacial mucosal margin despite heterogeneity among studies.

The papillary height is considered a crucial factor in esthetics. Even though the present study exhibited stable levels of mesial/distal papillae in both groups (<1 mm of change), the height of the papillae was low, leading to a long contact area of the implant prosthesis and an open embrasure space of varying extent. Scientific data demonstrated that the presence of the papilla in the interproximal area of an implant site is largely dependent on the vertical distance between the alveolar bone crest and contact point, as well as the horizontal distance between the implant and the neighboring implant/tooth (Choquet, V. et al., 2001, Tarnow, D. P. et al., 1992). However, it should be noted that in periodontally compromised sites presented in this study, the issue regarding presence of papilla or papilla fill is hard to evaluate properly, because a long contact area extending to the interproximal mucosal tissue could jeopardize proper oral hygiene due to inappropriate restoration contour (Katafuchi, M. et al., 2018).

PES is regarded as a parameter for assessing the esthetic outcomes. The PES score includes the mesial papilla, distal papilla, soft tissue level, curvature of the facial mucosa, and root convexity/soft tissue color and texture (Belser, U. C. et al., 2009). In the present study, the lack of papillary tissue mainly contributed to low PES scores (median value = 5 in both groups). The frequency of the highest score in each item was noted in the curvature of facial mucosa, indicating ARP and guided bone regeneration procedure are effective in gaining hard/soft tissue volume. It is

to be noted that no soft tissue augmentation was performed in this study. In order to improve esthetics, soft tissue volume augmentation could be necessary (Schneider, D. et al., 2011, Thoma, D. S. et al., 2014). This is also based on a study applying subepithelial connective tissue grafts concomitantly with ARP or implant placement in an extraction socket with buccal bone dehiscence, and demonstrated more favorable PES (11.4 ± 1.8) (Cosyn, J. et al., 2015).

Up to 1-year post-loading, no biologic complications were reported in either group. This was reflected by means of PD (2.83 - 3.25 mm), mSBI (1 in both groups), and mPI (0 in both groups) values, with no statistically significant differences between the groups. The stability of peri-implant health should be further monitored to evaluate the long-term success of the two treatment modalities.

Patient-reported outcome measures assessed by VAS demonstrated comparable discomfort levels between ARP and extraction only in the periodontally compromised sockets, suggesting ARP may be well accepted by patients. Notably, lack of VAS score superiority at the time of implant placement in group LP/ARP as compared to group EP, despite higher level of VAS in group EP, could be due to further bone augmentation in group LP/ARP. However, low VAS scores in both groups possibly might also indicate the influence of the surgical-friendly setting of the present trial.

Clinicians and patients may expect no further augmentation following ARP, but the current data indicate the high frequency of further bone augmentation (7 out of 9 patients in group LP/ARP) in periodontally compromised non-molar extraction sites. Such implies an increase of total treatment cost, which should be perceived by clinicians and informed to patients. Previous studies regarding ARP in compromised extraction sites also demonstrated such further augmentation (2 out of 15 patients in the study by Sun et al., and 21out of 94 patients in the study by Lee et al.) (Lee, J. S. et al., 2018, Sun, D. J. et al., 2019), but one should consider that those studies included both non-molar and molar extraction sites, unlike the present study.

The present study demonstrated no significant difference in terms of soft tissue levels, esthetic scores and patient's discomfort level between groups LP/ARP and EP in periodontally compromised extraction sites. Until now, no comparative study regarding implant placement protocols has done for such extraction sockets, which is special emphasis when interpreting the

result of the present study. However, some limitations should be also taken into account, such as the influence of additional bone augmentation in group LP/ARP on soft tissue level and PES, difficulty in standardization of the bone deficiency for periodontally compromised extraction site, and small sample size.

Conclusion

Late implant placement following alveolar ridge preservation and early implant placement led to comparable outcomes in periodontally compromised non-molar extraction sites in terms of soft tissue levels and periodontal parameters at 1-year post-loading, and patient's discomfort at the time of extraction/ARP and implant placement.

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Tables

Table 1. Demographic information

	Group LP/ARP (n = 9)	Group EP (n = 7)
Age (years)	58.11 ± 7.77	58.57 ± 15.57
Male/Female	8/1	3/4
Mandible/Maxilla	2/7	3/4
Reason for extraction (periodontal/fracture/endodontic)	9/0/0	7/0/0

Group LP/ARP: late implant placement following 4 months alveolar ridge preservation, Group EP: early implant placement

Table 2. Changes (*Δ*) in the soft tissue levels, periodontal parameters, and patient reported outcomes using the visual analog scale (VAS)

	Group LP/ARP	Group EP	*p*-value
Δ Midfacial mucosal margin	0.09 ± 0.63 0.03 (-0.35, 0.49)	0.1 ± 0.62 -0.19 (-0.31, 0.46)	0.983
Δ Mesial papilla	0.52 ± 0.5 0.62 (0.08, 0.79)	0.03 ± 0.99 0.29 (0.01, 0.33)	0.351
Δ Distal papilla	0.54 ± 0.57 0.25 (0.08, 1)	0.05 ± 0.72 -0.5 (-0.51, 0.71)	0.145
Probing depth	3.36 ± 0.91 3.25 (2.75, 3.5)	2.77 ± 0.16 2.83 (2.71, 2.83)	0.174
Modified plaque index	0.44 ± 0.73 0 (0, 1)	0 0 (0, 0)	0.299
Modified sulcus bleeding index	0.78 ± 0.83 1 (0, 1)	0.86 ± 0.69 0 (0.5, 1)	0.837
VAS (extraction or ARP)	2.22 ± 2.54 1 (1, 2)	2.14 ± 3.76 0 (0, 2.5)	0.408
VAS (implant placement)	1.11 ± 1.27 1 (0, 2)	3.43 ± 3.36 3 (1.5, 4)	0.114

Positive and negative numbers in the change of soft tissue levels indicate gain and loss of the tissue, respectively. Independent T-tests were used for *Δ* midfacial mucosal margin and *Δ* distal papilla. Wilcoxon rank-sum tests were used for the rest of the parameters.

Group LP/ARP: late implant placement following 4 months alveolar ridge preservation, Group EP: early implant placement

Table 3. Pink/white esthetic scores

Pink esthetic score (PES)

Group LP/ARP								Group EP								
Patient no.	Mesial papilla	Distal papilla	Curvature of facial mucosa	Level of facial mucosa	Color & texture	Root convexity/soft tissue	Sum	**Patient no.**	Mesial papilla	Distal papilla	Curvature of facial mucosa	Level of facial mucosa	Color & texture	Root convexity/soft tissue	Sum	***p*-value**
1	2	1	2	1	1	7		**1**	1	1	0	1	0	3		
2	1	0	1	2	1	5		**2**	2	1	2	1	1	7		
3	1	0	2	1	1	5		**3**	1	0	1	2	1	5		
4	1	0	2	1	1	5		**4**	1	1	2	1	1	7		
5	1	0	2	1	1	5		**5**	1	1	1	1	1	5		
6	1	1	2	1	1	6		**6**	0	1	1	1	1	4		
7	1	1	2	1	1	6		**7**	1	1	2	2	1	7		
8	1	0	1	1	1	4										
9	0	1	1	1	1	4										
			5.22 ± 0.97								5.43 ± 1.62					**0.758**
			5 (5, 6)								5 (4.5, 7)					

White esthetic score (WES)

Group LP/ARP								Group EP								
Patient no.	Tooth form	Outline/volume	Color (hue/value)	Surface texture	Translucency /Characterization	Sum		**Patient no.**	Tooth form	Outline/volume	Color (hue/value)	Surface texture	Translucency /Characterization	Sum	***p*-value**
1	1	2	2	2	1	8		**1**	2	2	1	1	0	6	
2	1	2	2	1	0	6		**2**	1	2	1	0	1	5	
3	1	2	2	1	2	8		**3**	1	2	1	2	2	8	
4	1	2	1	0	1	5		**4**	2	2	1	2	0	7	
5	1	2	2	2	1	8		**5**	1	2	0	1	0	4	
6	-	-	-	-	-	-		**6**	1	2	1	1	2	7	
7	1	2	1	0	1	5		**7**	2	2	2	1	0	7	
8	1	1	1	0	0	3									
9	1	1	2	1	1	6									
			6.13 ± 1.81								6.29 ± 1.38				**0.955**
			6 (5, 8)								7 (5.5, 7)				

Patient no. 6 was excluded in evaluating WES due to implant crown fracture. Group LP/ARP: late implant placement following 4 months alveolar ridge preservation, Group EP: early implant placement

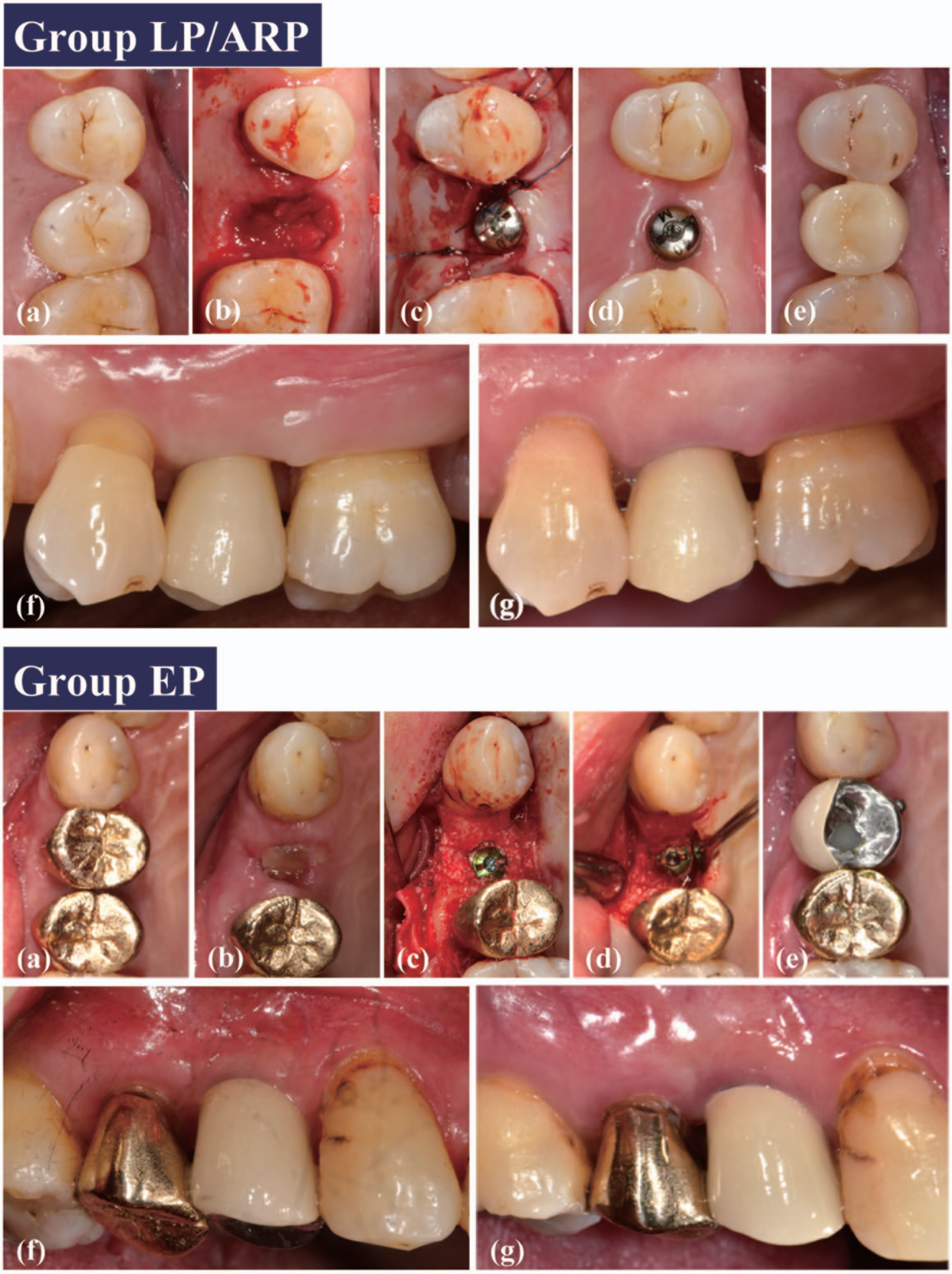
Figures

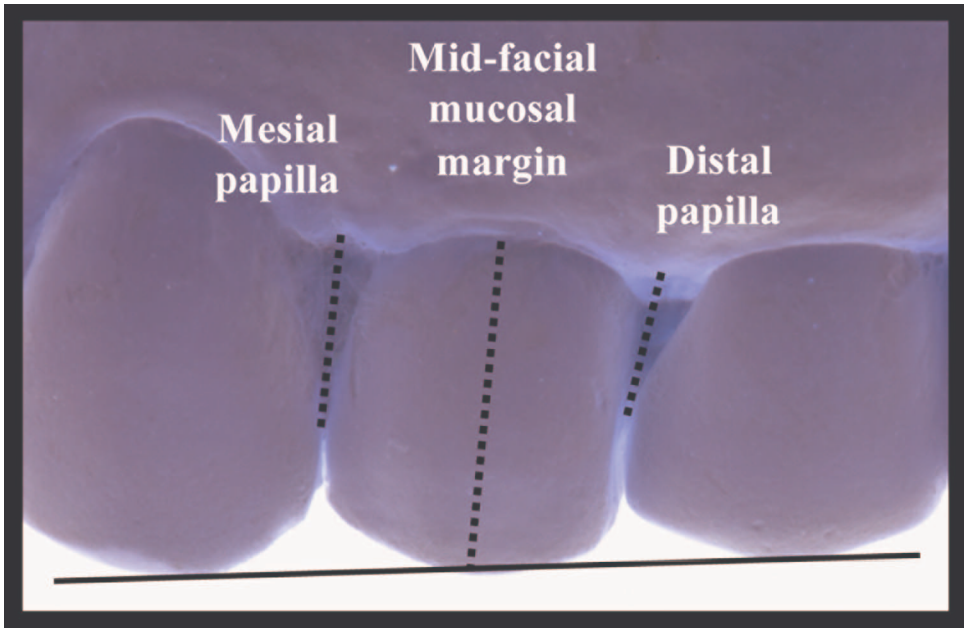
Figure 1. Representative photographs of groups LP/ARP (a-g) and EP (h-n).
Occlusal views (a) before extraction, (b) at the time of alveolar ridge preservation, (c) at the time of implant placement, (d) at 4 months post-implant placement, and (e) at 1-year post-loading; Facial views (f) immediately after final prosthesis insertion and (g) at 1-year post-loading; Occlusal views (h) before extraction, (i) at 8 weeks post-extraction, (j) at the time of implant placement and guided bone regeneration, (k) at 4 months post-implant placement, and (l) at 1-year post-loading; Facial views (m) immediately after final prosthesis insertion and (n) at 1-year post-loading
(LP/ARP: late implant placement following alveolar ridge preservation; EP: early implantation)

Figure 2. Measurement of the change of midfacial mucosal margin and mesial/distal papillae
Length of dotted lines was measured and the change of the length in each line was calculated

Figure 3. Consort diagram

Figure 4. Bar graphs of the changes of midfacial mucosal margin and mesial/distal papillae


Group LP/ARP
(a)
(b)
(c)
(d)
(e)
(f)
(g)
Group EP
(a)
(b)
(c)
(d)
(e)
(f)
(g)



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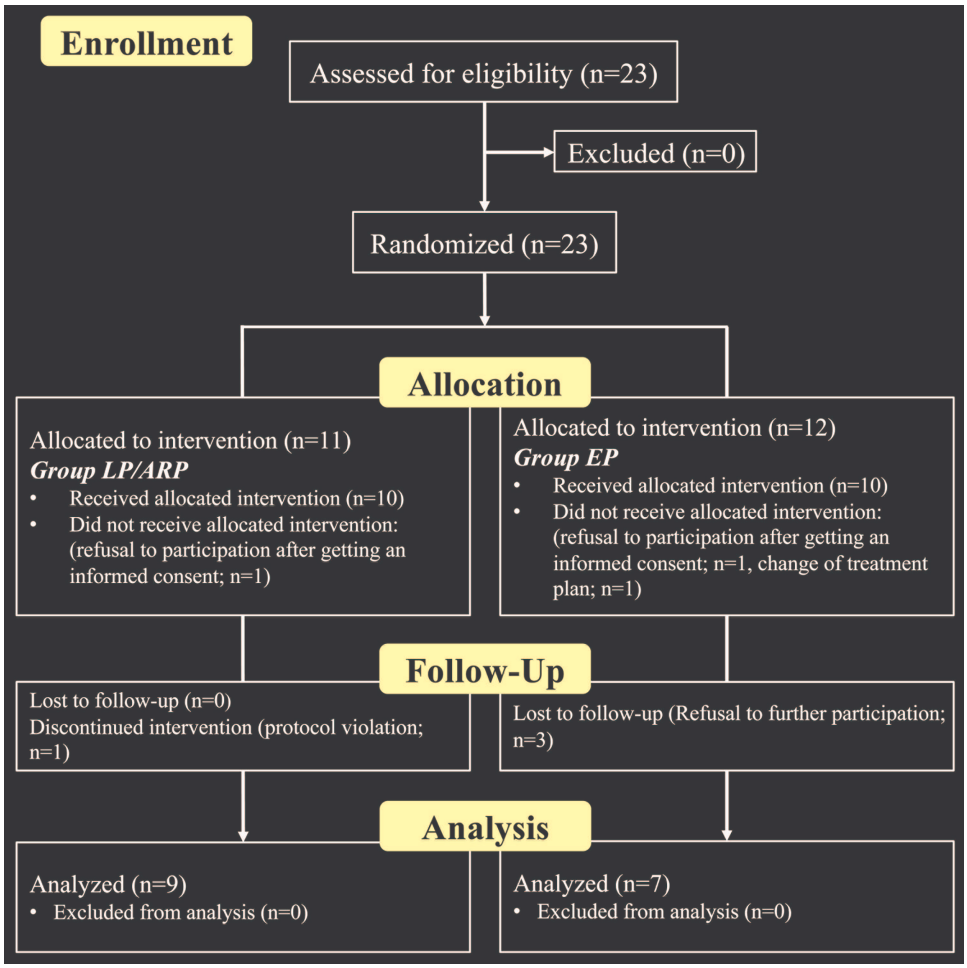

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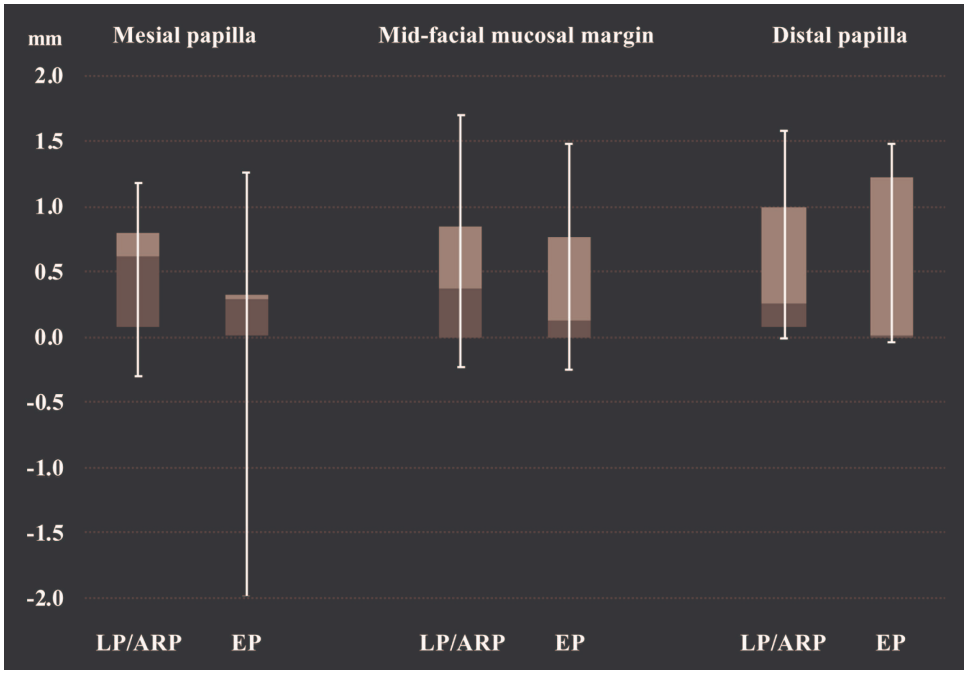

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